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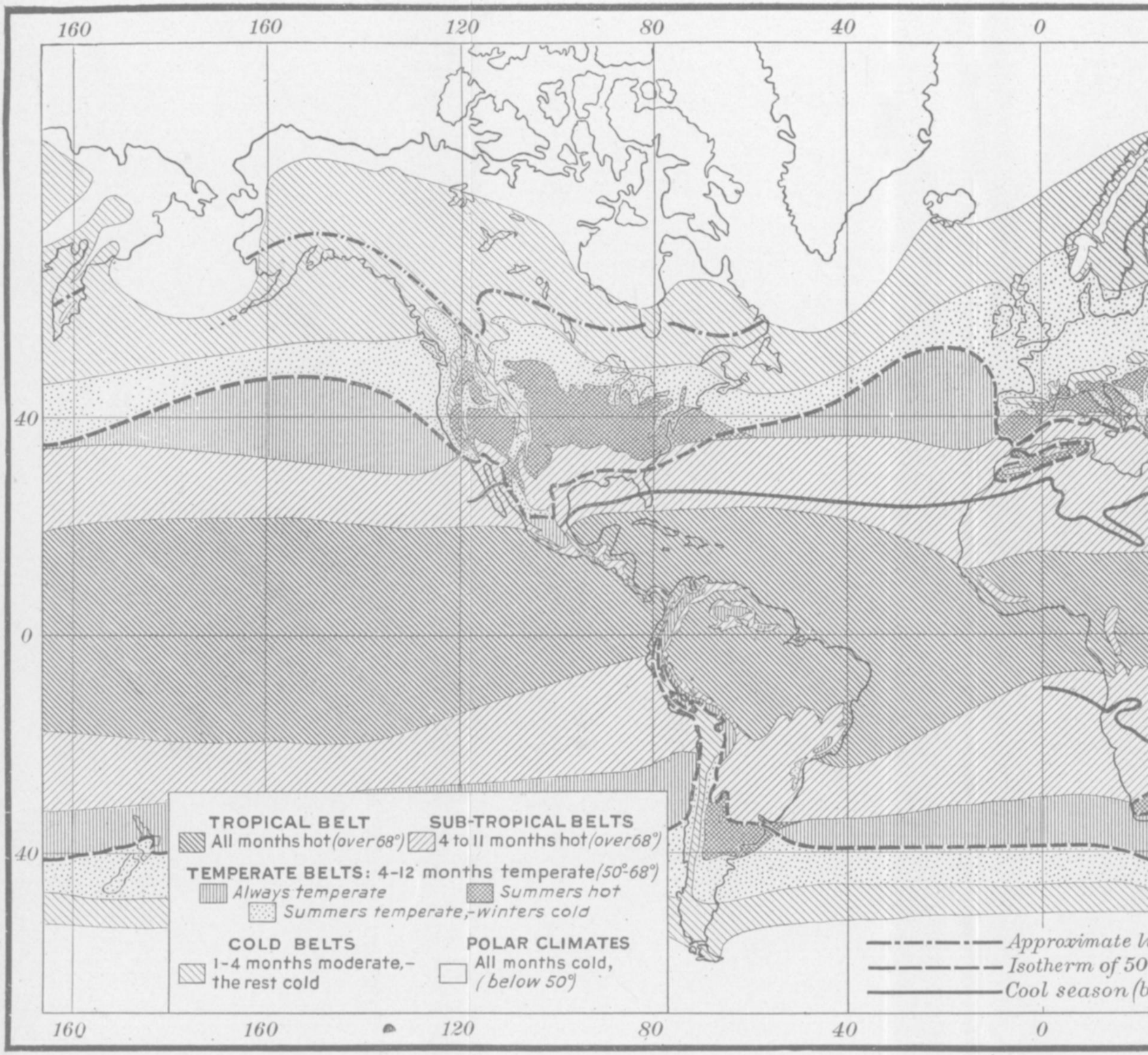
160
160
120
80
40
0
40
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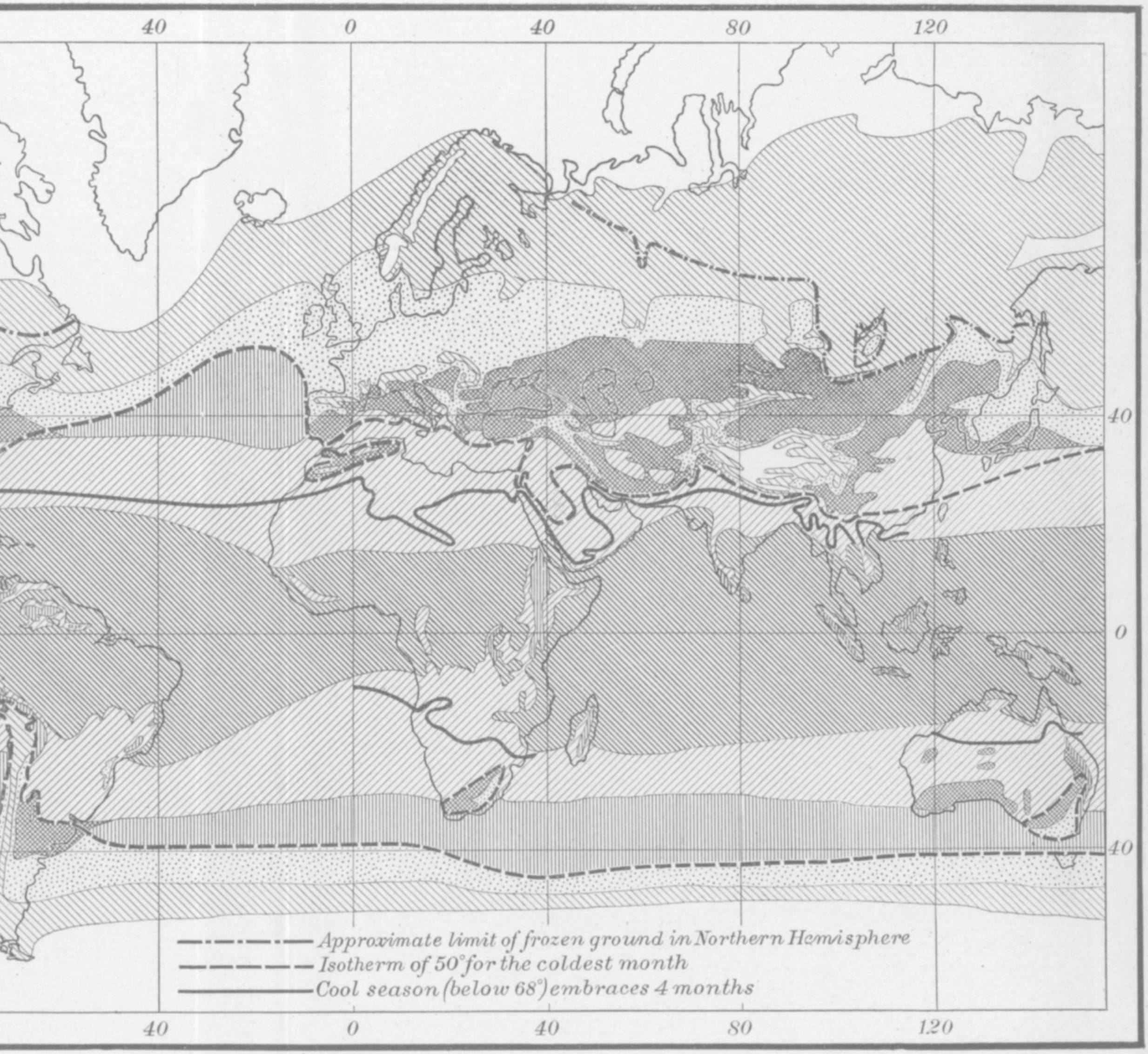
40
TROPICAL BELT
▧ All months hot (over 68°)
SUB-TROPICAL BELTS
▨ 4 to 11 months hot (over 68°)
TEMPERATE BELTS: 4-12 months temperate (50°-68°)
▥ Always temperate
▩ Summers hot
⬚ Summers temperate,-winters cold
COLD BELTS
▧ 1-4 months moderate,-the rest cold
POLAR CLIMATES
☐ All months cold, (below 50°)
Approximate l
Isotherm of 50
Cool season (b
160
160
120
80
40
0

Fig. 4.—TEMPERATURE ZONES AFTER KÖP


40
0
40
80
120
40
0
40
Approximate limit of frozen ground in Northern Hemisphere
Isotherm of 50° for the coldest month
Cool season (below 68°) embraces 4 months
40
0
40
80
120

4.—TEMPERATURE ZONES AFTER KÖPPEN.

BULLETIN

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THE CLIMATIC ZONES AND THEIR SUBDIVISIONS.*

BY

ROBERT DeC. WARD,

Harvard University.

(SYNOPSIS.)

Classification by latitude circles: the five classic zones; *Clima* as used by the Greeks; Ptolemy's climates; Parmenides; Polybius; Posidonius; Aristotle; Eudoxus; Strabo; Hippocrates.—Temperature zones: Supan; Köppen; Gebelin.—Wind zones: Davis; Woeikof.—Summary and conclusions.—Necessary subdivisions of the zones.

Classification by Latitude Circles.—So great is the variety of climates to be found in different parts of the world that it has long been customary to classify these climates roughly into certain broad belts. These are the climatic zones. A simple grouping of this kind can, however, obviously take account only of the most general characteristics of the climates which are included within each zone. The five zones with which we are most familiar are the so-called torrid, the two temperate, and the two frigid zones. The torrid, or better, the tropical zone, naming it by its boundaries, is limited on the north and south by the two tropics of Cancer and Capricorn, the equator dividing the zone into two equal parts. The temperate zones are limited towards the equator by the tropics, and towards the poles by the Arctic and Antarctic circles. The two frigid, or better, the two polar zones, are caps covering both polar regions, and bounded on the side towards the equator by the Arctic and Antarctic circles.

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* The following books have been made use of, in addition to the references mentioned in the foot-notes:

W. M. Davis: Elementary Meteorology, 334–335.
J. Hann: Handbuch der Klimatologie, II, 3–9.
W. Köppen: Klimalehre, 104–106.
A. Woeikof: Die Klimate der Erde, 327.

These five zones are classified on purely astronomical or mathematical grounds. They are really zones of sunshine, or of solar climate. Within the tropical zone the sun reaches the zenith at two different times in the year; its greatest possible zenith distance is 47°; the day is never less than ten and a half hours long. On the tropics themselves, the sun reaches the zenith but once a year. In the polar zones the sun is below the horizon for twenty-four hours at least once in winter, and is above the horizon for the same length of time at least once in summer. On the polar circles the noon altitude of the sun decreases to 0° on the shortest day. The temperate zone has conditions between these two extremes. At no point can the sun be in the zenith; nor, except on the polar circles, is there ever anywhere a twenty-four hour day or night.

The tropical zone has the least annual variation of insolation. It has the maximum annual amount of insolation. Its annual range of temperature is very slight. It is the summer zone. Beyond the tropics the contrasts between the seasons rapidly become more marked. The polar zones have the greatest variation in insolation between summer and winter. They also have the minimum amount of insolation for the whole year. They may well be called the winter zones, for their summer is so short and cool that the heat is insufficient for most forms of vegetation, especially for trees. The temperate zones are intermediate between the tropical and the polar in the matter of annual amount and of annual variation of insolation. Temperate conditions do not characterize these zones as a whole. They are rather the seasonal belts of the world. These five zones further differ more or less from one another in the character of their animals and plants and in the conditions of human life within their boundaries.

Taking the area of a hemisphere as unity, the relative areas of these zones are as follows:

Tropical	0.40
Temperate	0.52
Polar	0.08

This subdivision of the earth's surface on the basis of the geometrical distribution of sunshine dates from the time of the early Greek philosophers and geographers, but it is impossible to determine with certainty just when and by whom the various suggestions in this connection were made.*

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* Hugo Berger: *Geschichte der wissenschaftlichen Erdkunde der Griechen* (2d Ed. Leipzig, 1903), gives a discussion of the history of zonal classifications among the Greeks. See also H. Kiepert: *Lehrbuch der alten Geographie, Berlin*, 1878.

The word *clima* as used by the Greeks originally referred to the supposed slope of the earth toward the pole. It later came to be used, probably after Aristotle's time, as about equivalent to our *zone*, but did not at first have the same meaning as that word has with us. It was simply a mathematical or an astronomical term, and was not associated with any idea of physical climate. A change of location, to a place where the day was half an hour or an hour longer than at the starting-point, meant in those days a change of *climate*. Change of latitude was, however, gradually seen to mean change of temperature as well as change in length of day, and thus the word *clima* came to have its present meaning.* The division into climates was first applied to the northern hemisphere only, as there was no practical knowledge of the southern hemisphere.

An excellent illustration of the ancient meaning of the word *clima* is found in the system of climates proposed by the famous geographer Ptolemy, who lived in the second century A.D. Ptolemy used different schemes at different times, but the essential was a division of the earth's surface between equator and north pole into a series of climates, or parallel zones, separated by latitude circles and differing from one another simply in the length of their longest day. In the lower latitudes the breadth of a *clima* was fixed by the difference of a quarter of an hour in the length of the longest day, but in higher latitudes differences of half an hour, an hour, and finally a month, were the determining factors. Ptolemy's subdivision of the earth's surface was really nothing but an astronomical climatic table.†

Parmenides, who flourished about the middle of the fifth century B. C. proposed a five-zone division of the earth's surface not very unlike our present system. These zones were a torrid zone, uninhabitable because of heat; two frigid zones, uninhabitable because of cold; and two intermediate zones, of moderate temperature, suitable for man. The exact limits assigned to these zones are not known with certainty; but it is reasonable to suppose that the Arctic circle was even then recognized as a natural boundary for the north polar zone, and it is pretty clear that the temperate zone was much smaller, and the torrid zone much larger, than in our present classification. (See Fig. 1.‡)

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* Century Dictionary.

† F. A. Ukert: *Geographie der Griechen und Römer von den frühesten Zeiten bis auf Ptolemäus* (Weimar, 1816), Vol. 1, Part 2, p. 187, gives a tabulated scheme of Ptolemy's climates. See also Encyclopædia Britannica, article *Climate*.

‡ From H. Berger: *Geschichte der wissenschaftlichen Erdkunde der Griechen*. 2d Ed., Leipzig, 1903, p. 211.

The exact boundaries of the different zones varied more or less for some time, as astronomical knowledge became more and more exact, and as the habitable area of the earth's surface was gradually extended, but the scheme was generally adopted by later writers. Polybius (born about B. C. 204), however, divided his torrid zone into two parts by the equator, and Posidonius (born about B. C. 135) divided his torrid zone into three parts, making six and seven zones respectively. Aristotle (born B. C. 384) limited the torrid zone by the tropics and the north temperate zone by the Arctic circle, but there is doubt whether he really meant the fixed Arctic circle which we know. He believed both temperate zones habitable,* thus limiting the uninhabitable area to the astronomical tropical zone. Eudoxus, of Cnidus, who lived about B. C. 366, used a division of a quadrant of the earth's circumference into fifteen parts, of which four belonged to the torrid, five to the temperate, and six to the frigid zone. The Tropics were thus fixed at latitude 24°. Strabo (born about B. C. 54), opposed the prevailing view that the whole torrid zone, between the tropics, was uninhabitable, and also first clearly set forth the opinion that the temperature decreases with increasing altitude above sea-level, as well as with increasing latitude. As early as about 400 B. C., Hippocrates had endeavoured to show a causal relation between sunshine and the topography of a district on the one hand and the characteristics of its inhabitants on the other.†

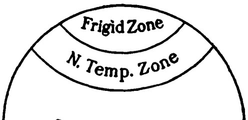

FIG. I.—THE ZONES IN THE TIME OF PARMENIDES.

Temperature Zones.—The classification of the climatic zones on the basis of the geometrical distribution of sunshine serves very well for purposes of simple description, but a glance at any isothermal chart shows at once that the isotherms do not coincide with the latitude lines. In fact, in the higher latitudes, the former often follow the meridians more closely than they do the parallels of latitude. The astronomical zones—*i. e.*, the zones of light—therefore differ a good deal from the zones of heat. Hence it has naturally been suggested that the zones be limited by isotherms rather than by parallels of latitude, and that a closer approach be thus made to the actual conditions of climate.

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* H. F. Tozer: *A History of Ancient Geography*, Cambridge, 1897, 179–180.

† The older views regarding the climates and the habitability of the five zones were thus stated by Virgil (Georgics I, 233–239, Translation by Davidson): " Five zones embrace the heavens; whereof one is ever glowing with the bright sun, and scorched forever by his fire; round which the two furthest ones to the right and left are extended, stiff with cerulean ice and horrid showers. Between these and the middle zones, two by the bounty of the gods are given to weak mortals; and a path is cut through both, where the series of the signs might revolve obliquely."

Supan* (see Fig. 2) has suggested limiting the hot belt, which corresponds to, but is slightly greater than, the old torrid zone, by the two mean annual isotherms of 68°—a temperature which approximately coincides with the polar limit of the trade winds and with the polar limit of palms. The latter is considered by Grisebach to be the truest expression of a tropical climate. The hot belt widens somewhat over the continents, chiefly because of the mobility of the ocean waters, whereby there is a tendency towards an equalization of the temperature between equator and poles in the oceans, while the stable lands acquire a temperature suitable to their own latitude. Furthermore, the unsymmetrical distribution of land in the low latitudes of the northern and southern hemispheres results in an unsymmetrical position of the hot belt with reference to the equator, the belt extending further north than south of the equator. The polar limits of the temperate zones are fixed by the isotherm of 50° for the warmest month. This is a much more satisfactory limit than the mean annual isotherm of 32°, which has also been suggested, for climates differing very widely from one another are found to have the same mean annual temperature of 32°. Summer heat is more important for vegetation than winter cold, and

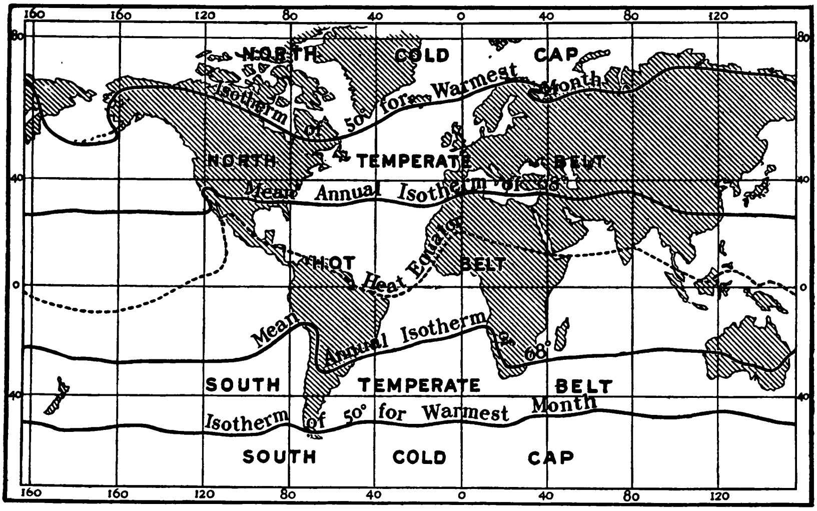
160
160
120
80
40
0
40
80
120
80
40
0
40
NORTH COLD CAP
Isotherm of 50° for Warmest Month
NORTH TEMPERATE BELT
Mean Annual Isotherm of 68°
HOT BELT
Heat Equator
Mean Annual Isotherm of 68°
SOUTH TEMPERATE BELT
Isotherm of 50° for Warmest Month
SOUTH COLD CAP

FIG. 2.—TEMPERATURE ZONES AFTER SUPAN (1896).

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* A. Supan: *Grundzüge der physischen Erdkunde.* Leipzig, 1896, 74-77.

where the warmest month has a temperature below 50°, cereals and forest trees do not grow, and man has to adjust himself to the conditions in a very special way. The two polar caps are not symmetrical as regards the latitudes which they occupy. The presence of extended land masses in the high northern latitudes carries the temperature of 50° in the warmest month farther poleward there than is the case in the corresponding latitudes occupied by the oceans of the southern hemisphere, which warm less easily and are constantly in motion. Hence the southern cold cap, which has its equatorial limits at about lat. 50° S., is of much greater extent than the northern polar cap. So far as this south polar zone is concerned, the presence or absence of an Antarctic continent is immaterial; for such a land mass must be ice-covered, and hence cannot operate to raise the temperature as in the case of a land surface to which the sun's rays have immediate access. The northern temperate belt, in which the great land areas lie, is much broader than the southern, especially over the continents. These temperature zones emphasize the natural conditions of climate more than can be the case in any subdivision by latitude circles, and they bear a fairly close resemblance to the old zonal classification of the Greeks.

Another, much more detailed classification, also proposed by Supan* (see Fig. 3), is as follows:

A. A warm zone, between the mean annual isotherms of 68°. This is subdivided into (*a*) a tropical belt, bounded on the north and south by the isotherm of 68° for the coldest month; (*b*) an extra-tropical belt, between the isotherm of 68° for the coldest month and the mean annual isotherm of 68°.

B. A temperate zone between the mean annual isotherms of 68° and 32°. This is subdivided into (*a*) the equatorial belt of the temperate zone, between the mean annual isotherms of 68° and the isotherm of 32° for the coldest month; (*b*) the polar belt of the temperate zone, beyond the isotherm of 32° for the coldest month.

C. A cold zone, on the polar side of the mean annual isotherm of 32°, characterized by permanently frozen ground. This is subdivided into (*a*) the equatorial belt of the cold zone, between the mean annual isotherm of 32° and the isotherm of 32° for the warmest month; (*b*) the polar belt of the cold zone, on the polar side of the isotherm of 32° for the warmest month.†

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* A. Supan: *Die Temperaturzonen der Erde*, Peterm. Mitth., XXV, 1879, 349-358.

† It may be noted that the isotherm of 32° is not found at sea-level in the July isothermal chart of the north polar regions (*Atlas of Meteorology*, Pl. 4). The isotherms in Fig. 3 are reproduced as originally drawn by Supan, and have not been changed to accord with recent observations.

The temperate zone, in this scheme, is smaller than that between the tropics and the polar circles. Both the other zones are larger than in the classic divisions. The ratio of the warm zone as a whole (*i. e.*, in both hemispheres), as compared with the temperate and cold zones in each hemisphere, is about as follows: Warm zone, 8; temperate zone, 3; cold zone, 1. As Hann has pointed out,* these temperature zones are no less unfortunately named in the higher latitudes than are the classic zones, for the reason that the mean annual temperature in a marine climate has a very different climatic significance from that of the same temperature in a continental climate. For example, southeastern Siberia and the larger portion of the Amoor territory are in the cold zone of Supan, although the summer temperature is higher than in central Germany. In the former region we find lofty forest trees, agriculture and cattle-raising, and in northern Manchuria deciduous forests grow on the lowlands. Again, although this district has the same mean annual temperature as central Greenland, there is the greatest difference in vegetation and in habitability. In high latitudes neither the mean annual temperature nor the temperature of the coldest month is nearly as important a climatic control over vegetation as is the temperature of summer, from the point of view of climate as a whole, and especially in relation to organic life. The summer tem-

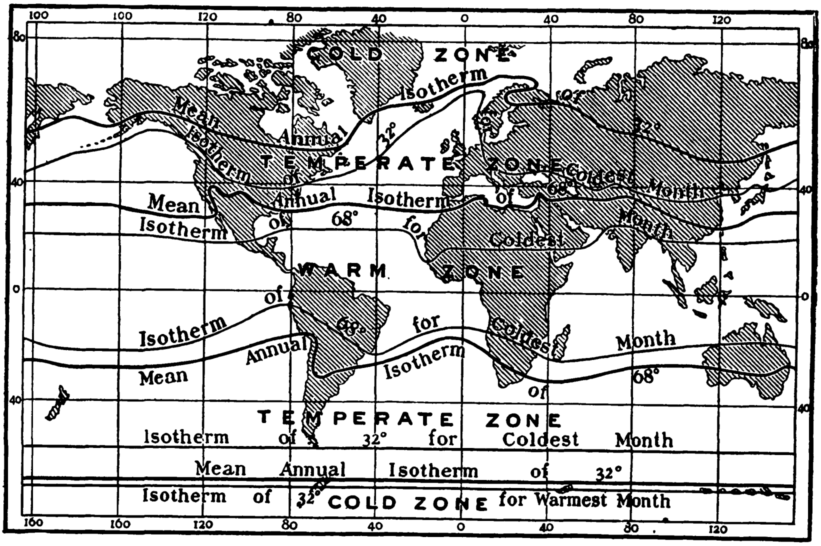
100
100
120
80
40
0
40
80
120
80
40
0
40
COLD ZONE
Isotherm
Mean Isotherm Annual of 32°
TEMPERATE ZONE
Isotherm of 32° for Coldest Month
Mean Annual Isotherm of 68°
Isotherm for Coldest Month of 68°
WARM ZONE
Isotherm of 68° for Coldest Month
Mean Annual Isotherm 68°
TEMPERATE ZONE
Isotherm of 32° for Coldest Month
Mean Annual Isotherm of 32°
Isotherm of 32° COLD ZONE for Warmest Month
160
160
120
80
40
0
40
80
120

FIG. 3.—TEMPERATURE ZONES AFTER SUPAN (1879).

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* J. Hann: *Handbuch der Klimatologie*, 1897, II, 6–7.

peratures determine habitability, the limits of plant growth, and the general conditions of human life. Hence, in the higher latitudes, zones bounded by mean annual isotherms are no great improvement over zones limited by latitude circles.

Another classification of temperature zones has been suggested by Köppen[*] (see Fig 4, facing p. 385).

Here the length of time during which the temperature remains within certain fixed limits, these limits having well-marked relations to organic life, is taken into account. Two critical daily mean temperatures, 68° and 50°, and the duration of these temperatures for periods of one, four, and twelve months, are the factors in this classification. These temperatures are not reduced to sea-level. A normal duration of a temperature of 50° for less than a month fixes very well the polar limit of trees and the limits of agriculture. Near this line are found the last groups of trees in the tundras. A temperature of 50° for four months marks the limit of the oak, and also closely coincides with the limits of wheat cultivation. North of the tree limit agriculture ceases, and man's food is to be sought very largely in the sea. With the approach to this line the period of plant growth is shortened more and more, agricultural operations become restricted, and occupations of other kinds are taken up. These critical temperatures and their varying periods of duration form the basis of the following classification:

1. Tropical belt: all months *hot* (over 68°). This is almost altogether within the tropics; it reaches, in round numbers, from latitude 20° N. to 16° S.
2. Sub-tropical belts: 4 to 11 months hot (over 68°); 1 to 8 months *temperate* (50°–68°).
3. Temperate belts: 4 to 12 months temperate.
4. Cold belts: 1 to 4 months temperate; the rest *cold* (below 50°).
5. Polar belts: all months cold.

The temperate belts of both hemispheres are further subdivided into three districts[†]—the steadily temperate belt[‡] is found only on the oceans; the belt of hot summers[§] only on the continents, and the third, with moderate summers and cold winters,[**] extends around the world, with the exception of a notable interruption over Siberia.

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[*] W. Köppen: *Die Wärmezonen der Erde, nach der Dauer der heissen, gemässigten und kalten Zeit und nach der Wirkung der Wärme auf die organische Welt betrachtet.* Met. Zeitschr., I, 1884, 215–226. Chart.

[†] All characterized by having at least four months temperate (50°–68°), and not more than four months hot (over 68°).

[‡] No month over 68° or below 50°.

[§] Has temperatures below 50° for one or more months.

[**] Has less than four months, but not less than one month, temperate (50°–68°).

In the second of these subdivisions, except in eastern North America and Asia, the rainfall is generally deficient; irrigation is more or less necessary, and deserts and steppes characterize the continental portions. Only in the monsoon districts of southern and eastern Asia, of Brazil, and of southeastern North America, do we find high temperatures combined with high relative humidity. The third subdivision above noted is now the chief seat of human development. Over a large part of the cold belt of the northern hemisphere the ground is permanently frozen, only thawing a little on the surface in summer. Nevertheless, in portions of it trees and hardy cereals grow. The polar belts are, as a whole, outside the limits of tree growth.

Another suggestion has been made by Gebelin,* who has proposed to select, as limits of the temperate zone, certain visible geographical boundaries, in contrast with the ideal climatic limits based upon the distribution of sunshine. On the oceans, the tropical circles serve as acceptable boundaries on the sides towards the equator, but on the continents the desert belts on both sides of the tropics are reasonable limits, although these deserts do not reach the eastern coasts of the continents. For the polar limits of the temperate zone the tundras are chosen on the continents, and the summer ice-masses on the oceans.

Wind Zones.—While a simple classification of the zones on the basis of temperature is an improvement upon any rigid scheme of division by latitude circles, the heat zones emphasize the element of temperature to the exclusion of such important elements as winds and rainfall. So distinctive are the larger climatic features of the great wind belts of the world, that a classification of climates according to wind systems has been suggested.† As the rain-belts of the world are closely associated with these wind systems, a classification of the zones by winds also emphasizes the conditions of rainfall. In such a scheme, the torrid, or tropical, zone, with its regularity of weather through the year, and the comparative simplicity of its climatic features, is bounded on the north and south by the margins of the trade-wind belts, and is therefore larger than the classic torrid zone. This trade-wind zone is somewhat wider on the eastern side of the oceans, and properly includes within its limits the equable marine climates of the eastern margins of the ocean basins, even as far north as latitude 30° or 35°. Most of the eastern coasts of China and of the United States are thus left in the more rigorous and more variable conditions of the north temperate zone. Through the middle of the trade-wind zone extends the subequatorial belt, with its migrating calms, rains, and monsoons. On the polar margins of the trade-wind zone lie the subtropical belts, of alternating trades and westerlies. The temperate zones, with the great irregularity of their weather phenomena and their marked seasonal changes, embrace the latitudes of the stormy westerly winds, having on the equatorward margins the subtropical belts, and being somewhat narrower than the classic temperate zones. Towards the poles there is no obvious limit to the temperate zones, for the prevailing westerlies extend beyond the polar circles. These circles may, however, serve fairly well as boundaries, because of their importance from the point of view of insolation. The polar zones in the wind classification, therefore, remain just as in the older scheme.

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* J. Gebelin. *Les Limites géographiques du climat tempéré.* Communication faite au Congrès National des Sociétés françaises de Géographie le 6 Août, 1895. Bordeaux, 1896.

† W. M. Davis. *Elementary Meteorology.* Boston, 1894, 334–335.

A compromise between the rigid division by latitude circles and the isothermal and wind classifications has been suggested by Woeikof,* who objects to limiting the torrid zone by the tropics on the ground that the high temperatures of that zone, as well as its characteristic winds, extend beyond these parallels. Latitude 30° would be a more natural boundary; but as the westerlies, which are characteristic of the temperate zones, prevail there in winter, latitude 25° is chosen as a compromise between 23½° and 30°. The polar zones are bounded by latitude 65°. When bounded by these several limits, the areas of the different zones are as follows:

Tropical Zone	417
Temperate Zones	490
Polar Zones	93
	1,000

Summary and Conclusions.—Reviewing what has been said regarding the climatic zones, it would seem that, all things considered, a simple division by isotherms, such as that suggested by Supan (1896), is the best for general use. The early division by latitude circles, while it has the merits of great simplicity, and emphasizes the all-important element of sunshine, is too arbitrary, and hence does not accord sufficiently well with the facts of actual climate. Nevertheless, we should not discard the classic zones without recognizing that they have a real meaning in relation to solar climate. The grouping of the climatic zones according to wind systems has much to recommend it from a meteorological standpoint, but is not quite simple enough for general use. Its adoption involves an understanding of the great wind and calm belts of the world, and of the migration of these belts. The shifting of the boundaries of the torrid zone also brings in an element of uncertainty which is somewhat confusing, although, as a place in the subtropical belt really changes its climate with the seasonal change from westerlies to trades, and *vice versa*, it may reasonably be expected to change its zone. In other words, actual climatic conditions are recognized; and in any case this is a more reasonable plan than to limit the torrid zone by means of the tropics, which arbitrarily cut across the trade-wind belts and separate areas which are climatically the same. The temperature zones proposed by Supan (1879) and by Köppen, while useful in special studies of plant distribution, are too detailed for general adoption.

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* A. Woeikof. *Die Klimate der Erde*, Jena, 1887, Part 1, 327.

Whatever climatic zones we adopt, we should certainly abandon the word *temperate* altogether as the designation of the middle zone in each hemisphere, and substitute some such adjective as *intermediate* for it. The words *torrid* and *frigid* should likewise disappear, and be replaced by *tropical* or *equatorial*, and *polar*.

Necessary Subdivisions of the Zones.—However we may classify them, the climatic zones are far from being uniform in character throughout their whole extent. Hence, no brief, simple description of the climate of a zone can be given. For this reason suggestions have been made regarding subdivisions of the different zones. Thus, in the case of the classic north temperate zone it has been proposed to subdivide it into subtropical, temperate, and subarctic, but the question how to limit these subdivisions is difficult to settle. A more rational scheme is that which, in view of the great differences in the climatic relations of land and water, recognizes a first large subdivision of each zone into land and water areas. Then, as continental interiors differ from coasts, and as windward coasts have climates unlike those of leeward coasts, a further natural subdivision would separate these different areas. Finally, the control of altitude over climate is so marked that plateaux and mountains may well be set apart by themselves as separate climatic districts. If each of the zones, whether bounded by latitude circles, or by isotherms, or by wind systems, be considered under these general subdivisions, as close an approach to actual conditions of climate will be made as is possible in general description.* Obviously, however, when the larger zones are subdivided to such an extent as is here suggested, we are dealing with a classification of climates rather than with climatic zones.

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* W. M. Davis, loc. cit.

THE ISLAND OF QUELPART.

BY

H. B. HULBERT.

The island of Quelpart lies some fifty miles off the southern coast of the Korean mainland, but only thirty from the outer edge of the line of islands that fringe the coast of the peninsula. It is, in all probability, geologically one with the range of mountains which forms the backbone of Korea, and which finally sinks beneath the waters of the sea off its southern coast. It is by far the largest of the thousands of islands which form the Korean Archipelago, being forty miles long from east to west and twenty-two miles wide from north to south. The whole island is dominated by the central peak, Mt. Auckland, or, as the Koreans call it, Hal-la San, which means, "The Peak which Reaches toward the Milky Way." The entire island is apparently formed by the sloping sides of this mountain, with its many subsidiary spurs. Its origin is manifestly volcanic, for a close examination reveals the fact that there were two distinct streams of lava which flowed from the ancient crater—one toward the north and one toward the southwest. Where the northern stream of lava reached the sea it is twenty miles wide, while the southern one at the sea-shore is thirty miles wide. This prevalence of lava on certain well-defined portions of the island gives rise to two distinct kinds of soil. Where the lava prevails the land is stony and sterile, but where the lava is not found the soil is a rich black mould. Two-fifths of the island are of the former kind and three-fifths of the latter. Toward the east and west the land slopes away to the sea in a long, beautiful sweep, but on the north and south the slopes are steep, and there are many deep gorges.